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Spatial Patterns in Meiofaunal Communities in Maluku, and Their Potential Uses as Biomonitors

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1. Introduction

Biological communities are often advocated as good means of assessing environmental quality (Pearson & Rosenberg 1978). They respond to short-term events, such as polluting chemical spills, but also integrate the effects of low levels of long-term environmental contaminants and other subtle changes, including climate change (e.g., Daan et al., 1996). In temperate aquatic environments, the most commonly followed organisms are the larger bottom-living animals—the macrofauna. In tropical areas, sessile benthic communities, particularly corals, are the usual target of reef monitoring programs (e.g., the regional study in Southeast Asia by the ASEAN – Australia Living Coastal Resources Project, ASEAN 1992). Reef surveys are often logistically difficult and expensive to carry out, and in severely degraded areas corals may be absent. Thus, there is a need to develop alternative scientific criteria to monitor reef status and health (Wilkinson 1993).

Sedimentary shores in these areas have coarse particle size and are well-drained, so that macrofauna are scarce. These organisms can therefore readily be used as biological indicators. Meiofauna are the microscopic multicelled animals that inhabit the interstices between the sand grains in coarse-grained sediments. The use of meiofauna as indicators of pollution has been advocated on many occasions (Warwick 1981, Raffaelli 1983, Coull & Chandler 1992, Uneputty & Evans 1997). This study sets out to describe the meiofauna of some shores in Maluku and to assess whether the pattern of environmental quality is matched by the

distribution of meiofauna. This would raise the possibility of using meiofauna for environmental monitoring in tropical regions.

The need to manage human impacts on the environment is now widely recognized. However, in order to manage effectively one must be able to quantify the system being managed. Only then can we test the effectiveness of degradation or recovery. Shorelines are in general readily accessible. A measure of environmental health based on shore biota would therefore be relatively easy to apply. This study aims to provide basic information on the nature of the meiofaunal communities of coral sand beaches in Maluku and to assess the effectiveness of intertidal meiofauna to act as bioindicators of environmental health.

2. Materials and methods

Samples were collected between August 1996 and February 1997 from 28 sites in Maluku ranging between highly urbanized areas, rural villages, and uninhabited islands (Fig. 1). At each site, five replicate 5cm x 5cm x 0.5cm samples of sediment were collected from the low water of neap tide level. The sample was immediately fixed by the addition of 4% formalin solution, containing the vital stain Rose Bengal. After fixation, the sample was washed over 1mm and 63 μ m meshes. The material retained on the 63 μ m mesh was then examined microscopically and the meiofauna identified and enumerated. Given the poor level of knowledge on the taxonomy of meiofauna from the region, specimens were classified only to family level or higher. Densities are expressed as individuals per g of sediment.

3. Results

Abundances were generally of the order of 38 individuals g⁻¹ but peaked at over 175 individuals g⁻¹ at Pantai Ai (site 11) on the north side of Ambon Bay. There was no clear pattern to meiofaunal abundances, with urban, rural, and uninhabited sites all showing similar levels of abundance (Fig. 2).

Diversity, as measured by the number of taxa recorded, did show a pattern. Around Ambon Bay, diversity was low at the most oceanic sites (3, 12, and 13), increased at sites further into the Bay (3–5 and 12–10), and was low around Ambon City (6–10). This implies that oceanic factors, probably wave action and anthropogenic effects, both influence diversity in the same way. The relatively lower diversity at inhabited

sites on Haruku (24, 27 vs. 25, 16) and Saparua (23 vs. 22) support the conjecture that anthropogenic factors can reduce species richness in these conditions. Diversity at the uninhabited island of Molanu (28) was comparable to that at the uninhabited sites at Banda (21), Haruku (25, 26), and Saparua (22). Excluding sites from within Ambon Bay, taxonomic richness was significantly lower at sites adjacent to human habitation (Kruskall-Wallis, $H_{adj} = 3.89$, $p=0.049$).

MDS ordination provides a robust means of assessing the similarity of composition of biological communities (Clarke & Warwick 1992). MDS analysis of the Ambon Bay samples clearly distinguishes site 8 (Tantui) and, to a lesser extent, sites 4 and 6 (Eri and Batu Capeu) (Fig. 3). The remaining stations were grouped, showing a similar distribution of individuals among the taxa recorded. The most oceanic sites, Seilale (3) and Laha (13), have similar diversities and taxonomic compositions.

The MDS plot for the rural islands shows a clear cluster of sites comprising Seram (19, 20) and Banda (21). The inhabited locations on Saparua (23) and Haruku (24, 27) tended to be displaced toward the bottom right of the plot. However, there is no clear way to distinguish “impacted” from clean sites in either the rural sites or Ambon Bay ordinations. Therefore, at least at the level of the “family,” faunistic composition does not change markedly in relation to urbanization and the associated anthropogenic impacts.

The ratio between the number of harpacticoid copepods and nematode worms has previously been advocated as a measure of oil and other pollution in sediments (Warwick 1981, Raffaelli 1983), although the generality of its use has been questioned (Coull et al. 1981). A small ratio (nematode dominance) has been interpreted as a sign of impact. Harpacticoid–nematode ratios in the present survey do not conform to this pattern, showing no significant difference in the ratio between uninhabited and inhabited locations (Kruskall-Wallis, $H_{adj} = 1.12$, $P>0.05$). Although harpacticoids were absent from sites 8 and 9, adjacent to Ambon City, they were also not recorded from one rural inhabited site and one uninhabited site on Haruku.

4. Discussion

Typically, the coral sand beaches of Maluku support a rich fauna of metazoans living in the interstices between the sand grains. Abundances are generally around 40 individuals per g of sediment. This contrasts

with the macrofauna on these beaches. Large organisms are rare or completely absent. The meiofauna therefore represent the group most influential in processing organic material, either produced by the beach microflora or carried in from adjacent terrestrial or marine ecosystems. Fenchel (1969), for example, showed that the ciliate component of the meiofauna alone was responsible for 8 times the metabolic activity of the macrofauna on the same sandy shores. Carbon turnover rates by macrofauna on temperate sandy shores are typically 10–50% of that by meiofauna (Gerlach 1971).

In addition to their role in productivity and material cycling, these meiofaunal communities typically contained individuals from about 9, and as many as 15, taxa in five core samples. This conforms with other studies (Higgins & Thiele 1988), with species richness typically varying between a few tens of species to several hundreds per m² (Bouwman 1987). Highest diversity is in subtidal sands from fully saline locations.

The lack of data from comparable systems means that the significance of this study's findings in terms of global biodiversity cannot be assessed at present. Even in the most studied locations in Europe and North America, new species of meiofauna are continually being described. For regions such as Indonesia, and remote locations such as Maluku, there is very little information on the species composition of the meiofauna. In this study we have chosen to use a coarser taxonomic basis in order to assess their suitability as bioindicators. However, the levels of diversity recorded at the family level suggest that these communities have a high β -diversity and that efforts should be made to inventory this resource.

Their small size (high body surface to volume ratio) and intimate contact with the sediment means that meiofauna are exposed to pollutants in the sediments. Many meiofaunal groups have been shown to be sensitive to such pollution (see Coull & Chandler 1992 for a review) and thus can potentially be used as bioindicators of environmental health. In this study we have shown that meiofaunal diversity, even at the relatively coarse taxonomic resolution used here, is affected by human impacts, but also by increased natural stress such as wave action. While diversity did provide a measure of environmental stress (natural and anthropogenic), neither productivity nor community structure responded in a consistent manner to pollution. The former was not unexpected. Studies of macrofaunal communities often show no change, or even an increase in productivity, at the lower diversity impacted sites. This is a case of tol-

erant species benefiting from the absence of competitors that are more sensitive to pollution (Pearson & Rosenberg 1978). The minimal change in community structure that accompanied the marked changes in diversity implies that the response is one of pollution “knocking out” rare taxa, these being represented by only 1 or 2 individuals per sample. There is thus no marked shift in community composition. Uneputti and Evans (1997) have previously shown an increase in meiofaunal densities beneath stranded plastic litter on the upper shore, with the changes being of sufficient magnitude to alter community composition. In this study, lower-shore meiofaunal communities have been shown not to be significantly different on shores subject to human impacts. This highlights the importance of considering the scale of observation. At the level of the shore, community composition was not altered, but diversity was reduced, while under pieces of litter, diversity was raised and community structure was altered. This was probably because the litter reduced evaporation and so promoted damp conditions in the sediment and/or the association of increased levels of organic matter with the litter (Uneputti & Evans 1997).

These subtle changes in community composition were also reflected in the lack of a significant change in the harpacticoid-to-nematode ratio. This ratio has previously been used to assess pollution gradients away from individual industrial outfalls (Warwick 1981, Raffaelli 1983; see also Coull et al. 1981). It would appear not to be of sufficient sensitivity to detect low-level impacts arising from wastes from rural communities.

Overall, this study has shown coral sand meiofaunal communities in Maluku to be rich and biologically productive. There is also good evidence of loss of biodiversity with exposure to human impacts. There is thus scope for using meiofaunal communities as bioindicators. The low level of taxonomic resolution enforced by our lack of knowledge of these communities makes these findings provisional. It does, however, emphasize the need for more detailed studies on these communities.

5. Summary

The coral sand beaches of the islands of Maluku contain very few large animals. However they support a rich and diverse fauna of microscopic animals living in the spaces between the sand grains. This fauna appears to be more diverse at sites away from human habitation, and its associated impacts, and those not exposed to the full force of storm waves.

There is therefore scope for developing techniques of biological monitoring using this group to assess environmental health. Such developments will require advances to be made in inventorying this biodiverse resource.

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Figure 1. Location of sampling sites. Ambon Bay: (1) Namalatu Beach, (2) Santai Beach, (3) Seilale, (4) Eri, (5) Amatusu, (6) Batu Capeu, (7) Benteng, (8) Tantui, (9) Galala, (10) Rumah Tiga, (11) Pantai Ai, (12) Hatiwe Besar, (13) Latia; Baguala Bay: (14) Toisapu, (15) Passo, (16) Svatsepa, (17) Suli; East Coast: (18) Tulehu; West Seram: (19) Marsegu Island, (20) Waipirit; Karaka Islands: (21) Banda Island; Saparua Island: (22) Sirsawoni, (23) Porto; Haruku Island: (24) Kailolo, (25) Kariu, (26) Waimital, (27) Hulaliu; (28) Molana Island.

Figure 2. Mean (n=5) abundance (per g of dry sediment) and taxonomic richness (total for 5 cores) at 28 sampling locations in Maluku (● total abundance (mean), ▲ spp. richness).

Figure 3. Nonmetric Multi-Dimensional Scaling (MDS) ordinations for taxonomic composition of samples from (top: 1–18) sites on Pulau Ambon and (bottom: 19–28) other islands in Maluku.

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